CLAIMS

Therefore, having thus described the invention, at least the following is claimed:

1. A composition, comprising:

a metal nitrate selected from d-block metal nitrates and f-block metal nitrates; and

a metal salt having weakly bound counter anions, wherein the metal of the metal salt having weakly bound counter anions is selected from a d-block metal and an f-block metal.

2. The composition of claim 1, wherein the metal nitrate is selected from iron (III) nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate and cerium (IV) nitrate.

3. The composition of claim 1, wherein the metal salt having weakly bound counter anions is selected from copper (II) perchlorate, copper (II) trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

4. The composition of claim 1, wherein the metal nitrate is selected from iron (III) nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate and cerium (IV) nitrate, and wherein the metal salt having weakly bound counter anions is selected from copper (II) perchlorate, copper (II) trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

5. The composition of claim 1, wherein the metal nitrate is copper nitrate and the metal salt having weakly bound counter anions is copper trifluoromethanesulfonate.

6. The composition of claim 1, further comprising a polyoxometalate.

7. The composition of claim 6, wherein the polyoxometalate has the formula $A[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^{y-}$, wherein A includes at least one counterion selected from alkali metal cations, alkaline earth metal cations, ammonium cations, quaternary ammonium cations, d-block cations, f-block cations, and combinations thereof, wherein M includes at least one element selected from an f-block element and a d-block element having at least one d-electron, except for vanadium, molybdenum, tungsten, niobium, or tantalum, wherein X includes at least on element selected from a p-block element, a d-block element, and an f-block element, except for oxygen, wherein k can range from 0 to 30, wherein m can range from 0 to 160, wherein n can range from 0 to 160, wherein o can range from 0 to 30, where p can range from 0 to 10, wherein q can range from 0 to 30, wherein r can range from 0 to 30, wherein s is a number so that y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or equal to four; and wherein the sum of k, m, and q is greater than zero.

8. The composition of claim 6, wherein the polyoxometalate has the formula $[X^gV_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^{u-}[A]$, wherein X is at least one p-, d-, or f-block element; g is greater than or equal to 2; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; h is from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten, molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6; u is from 3 to 9; and A is a counterion.

9. The composition of claim 6, wherein the polyoxometalate has the formula $[X^gV_b^{j+}Z_{12-b}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and a is from 3 to 9.

10. The Composition of claim 6, wherein the polyoxometalate has the formula $[X^{g+}M_c^{h+}Z_{12-c}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a is from 3 to 9.

11. The composition of claim 6, wherein the polyoxometalate has the formula $[X_2^{r+}V_u^{s+}M_v^{t+}Z_{18-u-v}^{y+}O_z]^{w-}[A]$, wherein X is at least one p-, d-, or f-block element; r is greater than or equal to 1; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; t is from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium, or a combination thereof; a is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or 62; w is greater than or equal to 4; and A is a counterion.

12. The composition of claim 6, wherein the polyoxometalate has the formula $[X_2^{r+}V_u^{s+}Z_{18-u}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9; and w is greater than or equal to 4.

13. The composition of claim 6, wherein the polyoxometalate has the formula $[X_2^{r+}M_v^{t+}Z_{18-v}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is greater than or equal to 4.

14. The composition of claim 6, wherein the polyoxometalate has the formula $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or aluminum; Z is tungsten or molybdenum; p is from 1 to 6, and A is a counterion.

15. The composition of claim 6, wherein the metal nitrate is selected from iron (III) nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate and cerium (IV) nitrate.

16. The composition of claim 6, wherein the metal salt having weakly bound counter anions is selected from copper (II) perchlorate, copper (II) trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

17. The composition of claim 6, wherein the metal nitrate is selected from iron (III) nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate and cerium (IV) nitrate, and wherein the metal salt having weakly bound counter anions is selected from copper (II) perchlorate, copper (II) trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

18. The composition of claim 6, wherein the polyoxometalate is selected from $TBA_6Fe_3PW_9O_{37}$, wherein TBA is tetra-*n*-butylammonium; $TBA_6V_{10}O_{28}$, $TBA_5PV_2Mo_{10}O_{40}$; $TBA_6Fe_3PW_9O_{37}$; $TBA_9Fe_3(A\text{-}PW_9O_{34})_2$; and $TBA_{12}Fe(OH_2)_2Fe_2(P_2W_{15}O_{56})_2$.

19. The composition of claim 18, wherein the metal nitrate is copper nitrate and the metal salt having weakly bound counter anions is copper trifluoromethanesulfonate.

20. The composition of claim 1, wherein the composition is included in a material.

21. The composition of claim 6, wherein the composition is included in a material.

22. The composition of claim 20, wherein the material being selected from a fabric, a topical carrier, powder, and a coating.

23. The composition of claim 21, wherein the material being selected from a fabric, a topical carrier, powder, and a coating.

24. A method of removing a contaminant, comprising:

contacting the composition of claim 1 with the contaminant.

25. The method of claim 24, wherein the composition is included in a material.

26. The method of claim 25, wherein the material being selected from a fabric, a topical carrier, powder, and a coating.

27. A method of removing a contaminant, comprising:

contacting the composition of claim 6 with the contaminant.

28. The method of claim 27, wherein the composition is included in a material.

29. The method of claim 28, wherein the material selected from a fabric, a topical carrier, powder, and a coating.

30. A composition, comprising:

a first polyoxometalate having a first metal selected from a d-block metal and an f-block metal, wherein the first metal being an open coordinate site of the first polyoxometalate, and wherein the first metal has a nitrate terminal ligand; and

a second polyoxometalate having a second metal selected from a d-block metal and an f-block metal, wherein the second metal being an open coordinate site of the second polyoxometalate, and wherein the second metal has a halide terminal ligand.

31. The composition of claim 30, wherein the halide terminal ligand is a bromide terminal ligand.

32. The composition of claim 31, wherein the second metal is selected from iron (III) and copper (II).

33. The composition of claim 32, wherein the first metal is selected from iron (III), copper (II), cerium (III), and cerium (IV).

34. The composition of claim 30, wherein the first metal is selected from iron (III), cobalt (II), nickel (II), copper (II), cerium (III), and cerium (IV).

35. The composition of claim 30, wherein the first metal is selected from iron (III), copper (II), cerium (III), and cerium (IV).

36. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $A[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^{y-}$, wherein A includes at least one counterion selected from alkali metal cations, alkaline earth metal cations, ammonium cations, quaternary ammonium cations, d-block cations, f-block cations, and combinations thereof, wherein M includes at least one element selected from an f-block element and a d-block element having at least one d-electron, except for vanadium, molybdenum, tungsten, niobium, or tantalum, wherein X includes at least on element selected from a p-block element, a d-block element, and an f-block element, except for oxygen, wherein k can range from 0 to 30, wherein m can range from 0 to 160, wherein n can range from 0 to 160, wherein o can range from 0 to 30, where p can range from 0 to 10, wherein q can range from 0 to 30, wherein r can range from 0 to 30, wherein s is a number so that y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or equal to four; and wherein the sum of k, m, and q is greater than zero.

37. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X^gV_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^{u-}[A]$, wherein X is at least one p-, d-, or f-block element; g is greater than or equal to 2; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; h is from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten, molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6; u is from 3 to 9; and A is a counterion.

38. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X^{g}V_{b}^{j+}Z_{12-b}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and a is from 3 to 9.

39. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X^{g+}M_{c}^{h+}Z_{12-c}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a is from 3 to 9.

40. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X_{2}^{r+}V_{u}^{s+}M_{v}^{t+}Z_{18-u-v}^{y+}O_{z}]^{w-}[A]$, wherein X is at least one p-, d-, or f-block element; r is greater than or equal to 1; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; t is from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium, or a combination thereof; a is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or 62; w is greater than or equal to 4; and A is a counterion.

41. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X_{2}^{r+}V_{u}^{s+}Z_{18-u}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9; and w is greater than or equal to 4.

42. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[X_{2}^{r+}M_{v}^{t+}Z_{18-v}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is greater than or equal to 4.

43. The composition of claim 30, wherein the first polyoxometalate further comprises the formula $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or aluminum; Z is tungsten or molybdenum; p is from 1 to 6, and A is a counterion.

44. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $A[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^{y-}$, wherein A includes at least one counterion selected from alkali metal cations, alkaline earth metal cations, ammonium cations, quaternary ammonium cations, d-block cations, f-block cations, and combinations thereof, wherein M includes at least one element selected from an f-block element and a d-block element having at least one d-electron, except for vanadium, molybdenum, tungsten, niobium, or tantalum, wherein X includes at least on element selected from a p-block element, a d-block element, and an f-block element, except for oxygen, wherein k can range from 0 to 30, wherein m can range from 0 to 160, wherein n can range from 0 to 160, wherein o can range from 0 to 30, where p can range from 0 to 10, wherein q can range from 0 to 30, wherein r can range from 0 to 30, wherein s is a number so that y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or equal to four; and wherein the sum of k, m, and q is greater than zero.

45. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X^gV_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^{u-}[A]$, wherein X is at least one p-, d-, or f-block element; g is greater than or equal to 2; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; h is from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten, molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6; u is from 3 to 9; and A is a counterion.

46. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X^{g}V_{b}^{j+}Z_{12-b}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and a is from 3 to 9.

47. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X^{g+}M_{c}^{h+}Z_{12-c}^{i+}O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a is from 3 to 9.

48. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X_{2}^{r+}V_{u}^{s+}M_{v}^{t+}Z_{18-u-v}^{y+}O_{z}]^{w-}[A]$, wherein X is at least one p-, d-, or f-block element; r is greater than or equal to 1; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; t is from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium, or a combination thereof; a is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or 62; w is greater than or equal to 4; and A is a counterion.

49. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X_{2}^{r+}V_{u}^{s+}Z_{18-u}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9; and w is greater than or equal to 4.

50. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[X_{2}^{r+}M_{v}^{t+}Z_{18-v}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is greater than or equal to 4.

51. The composition of claim 30, wherein the second polyoxometalate further comprises the formula $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or aluminum; Z is tungsten or molybdenum; p is from 1 to 6, and A is a counterion.

52. The composition of claim 34, wherein the first polyoxometalate is selected from $TBA_{9-x}H_x[A\text{-}\alpha\text{-}(Fe(NO_3))_3PW_9O_{37}]$, $TBA_{12-x}H_x[A\text{-}\alpha\text{-}(Cu(NO_3))_3PW_9O_{37}]$, $TBA_{9-x}H_x[A\text{-}\alpha\text{-}(Ce(III)(NO_3))_3PW_9O_{37}]$, and $TBA_{6-x}H_x[A\text{-}\alpha\text{-}(Ce(IV)(NO_3))_3PW_9O_{37}]$.

53. The composition of claim 44, wherein the second polyoxometalate is $TBA_{12-n-x}Na_n[A\text{-}\alpha\text{-}(CuBr)_3PW_9Br_xO_{37-x}]$ and $TBA_{12-n-x}Na_n[A\text{-}\alpha\text{-}(FeBr)_3PW_9Br_xO_{37-x}]$.

54. The composition of claim 30, wherein the composition is included in a material.

55. The composition of claim 54, wherein the material selected from a fabric, a topical carrier, powder, and a coating.

56. A method of removing a contaminant, comprising:

contacting the composition of claim 30 with the contaminant.

57. The method of claim 56, wherein the composition is included in a material.

58. The method of claim 57, wherein the material selected from a fabric, a topical carrier, powder, and a coating.